obituary

Lars Onsager, who died on October 5, 1976, was undoubtedly one of the great scientists of the 20th century. His publications were neither lengthy nor numerous. When he was awarded the Nobel prize in Chemistry for 1968 for his discovery of "Reciprocal relations in irreversible processes", the citation noted that the publication (two papers in *Physical Review*[1] containing 22 and 15 pages respectively) was one of the smallest ever to be awarded a Nobel prize.

Onsager's total publication list runs to some 60 papers, a number which can readily be matched by most university professors of science. But the quality of his publications is superb, and he did not put his name to anything trivial or unfinished. Besides non-equilibrium thermodynamics, a field initiated by his Nobel prize work, there are at least five fields his contributions to which ensure him a place of distinction. In the area of phase transitions many regard his exact solution of the two-dimensional Ising model as of comparable significance to his Nobel prize work; and in the theory of electrolytes, liquid helium, metals and ice, many of his ideas have by now been incorporated into standard texts. He also devoted thought and attention to the problem of turbulence in fluids. He provided a magnificent counter-example to the "publish or perish" philosophy which has influenced so many scientists during the past few decades; and there was a general consensus of opinion among those who had direct contact with him that the unpublished contents of his drawers would have sufficed to establish the reputations of quite a few scientists with less exacting standards than his own.

Despite the clarity of his thinking and writing Onsager was a poor lecturer, and usually pitched his exposition far above the heads of the audience. This was not due to any conscious desire to show off (which was quite alien to his nature), but to a complete lack of appreciation of the gap between himself and his listeners. An incident which occurred during his sabbatical leave at Cambridge in 1951–1952 illustrates this well. Onsager was asked to talk to the Kapitza Club about his work with Bruria Kaufman on the Ising model. The Kapitza Club (named after its founder) aims to provide a meeting-ground between theoretical and experimental physicists. In

Photograph taken by Z. R. Hasan, a graduate student of Temple University, during a visit by Onsager a few months before his death.

his briefing Onsager was warned that since there would be experimentalists present he should phrase his talk in a language which would be intelligible to them. Nevertheless, he started with the mathematics of spinors. After a few minutes the thought occurred to him that some of the audience might not have come across spinors before, and he turned to ask if there was anyone present who did not know what a spinor was. One or two brave spirits raised their hands, and Onsager said "Right, I will tell you; spinors are matrices isomorphic with the rotation group in three dimensions" and he continued his talk assuming that this was a sufficient explanation for an experimental physicist!

During the same year he gave a seminar at Oxford about his ideas on the theory of liquid helium, and on this occasion even the theorists were at a loss in trying to follow his arguments. Onsager's final comment in reply to a discussion question was "The results are not bad when you consider the enormity of the swindle which I have perpetrated". It was only a few years later when Feynman's theory of liquid helium appeared with acknowledgements to Onsager's ideas that light was shed retrospectively on what Onsager had been trying to convey in the seminar.

In spontaneous discussion at conferences he came over better, and was often entertaining as well as informative. Onsager would get up at the end of a long and sophisticated lecture and say "I think Dr X has tackled this problem in a very effective manner, and his first approximation is in the right direction; if he proceeds to a second approximation he should find the following . . ." And he had an endearing habit of going to the front of a distinguished audience, and turning to them with a beaming smile to ask practical down-to-earth questions like a schoolteacher. "Does anyone know what is the best substance to use to illustrate A, B, C? Well, it is sulphur, because . . ."

His knowledge of different aspects of science was immense. When taken round a laboratory he would comment pertinently on every detail of the experimental set-up, to the great surprise of the experimentalists who knew of him only as an abstruse theoretician. And he took it for granted that every research scientist would be familiar with all text-book material—"But it's in all the standard books on palaeontology".

In private discussion it was much easier to communicate with Onsager provided that you were courageous enough to persist in questioning when you did not understand. He would drop the level one stage at a time until the gap could be bridged. Thus he had many disciples and collaborators who uniformly testify to his generosity, and to the inspiration of working with him on scientific problems.

Onsager was born in Norway in 1903. He entered the Norges Tekniske Hogskole in Trondheim in 1920; his first research ideas developed here and were concerned with the theory of electrolytes. After graduating in 1925 he went to the Eidgenössische Technische Hochschule in Zurich to work with Debye and Hückel, and his first publications[2] were devoted to a revision of the Debye–Hückel theory.

In fact, it was the combination of diffusion and electrical conduction in electrolytes for which he found that reciprocal relations were satisfied which led Onsager to a deeper study of their origin. Although the second law of thermodynamics gives precise information when applied to equilibrium phenomena and reversible processes, for irreversible processes it provides only the qualitative information that the entropy increases. Kelvin had attempted to extend thermodynamics beyond the equilibrium state in his theory of thermoelectricity, and Helmholtz had derived a "Principle of least dissipation" which Onsager recognised as being equivalent to the reciprocal relations. Onsager had also been thinking about the condition of detailed balancing used widely in the theory of chemical reactions and usually taken to be a consequence of the second law. He became convinced that there was nothing in the second law to prevent equilibrium being maintained by cyclic processes when there were more than two independent reactions. A new hypothesis of microscopic reversibility was needed to exclude this possibility.

In his Nobel prize papers[1] published in 1931 Onsager tied all these ideas together, and showed that the reciprocal relations and principle of least dissipation could be derived from this hypothesis. He thereby established a new branch of thermodynamics. For some years little attention was paid to his papers; but in the post-war era the subject of irreversible thermodynamics gained momentum steadily and numerous applications arose in physics, chemistry and biology as well as in technology.

In 1928 Onsager had emigrated to the USA. He spent one term at Johns Hopkins University and five years at Brown University. In 1933 he went to Yale where he stayed until his retirement in 1972; from 1945–72 he served as Josiah Willard Gibbs Professor of Theoretical Chemistry.

His classic paper giving the solution of the two-dimensional Ising model[3] was published in 1944. The paper was a mathematical *tour de force* and amongst other skills showed remarkable dexterity in handling elliptic and elliptic modular functions. (Onsager once confided to Elliott Montroll that whilst a student he had worked through every example in Whittaker and Watson's *Modern Analysis*!) For the first time the exact statistical mechanics of a realistic model of interacting systems became available. Ideas about the nature of critical points and the behaviour of thermodynamic functions in their neighbourhood had to be completely revised; the publication laid the foundation of the modern era of phase transitions.

The 1944 paper dealt with thermodynamic functions in equilibrium. Of no less importance are the correlations between spins at different distances, and in collaboration with Bruria Kaufman[4] Onsager published a paper in 1949 devoted to their behaviour. In the same year he announced cryptically at a conference in Florence[5] that he and B. Kaufman had also solved the problem of long-range order for a rectangular net and that it was simply $(1-k^2)^{1/8}$ (where k is a simple function of the interactions). This was a result of the greatest importance, which was rederived independently by Yang[6] in 1952. Onsager never published any details of his derivation, and gave no clue to the mathematics he had used. It was only twenty years later at a conference in Gstaad to celebrate the 25th anniversary of the publication of his 1944 paper that some information was forthcoming[7]. In computing the long-range order he had been led to a general consideration of Toeplitz matrices, but he did not know how "to fill out the holes in the mathematics, the epsilons and deltas", and by the time he had achieved this satisfactorily he found that "the mathematicians got there first".

There are many jewels to be found among Onsager's publications and those of others which incorporate his ideas; like the duality relation in two-dimensional Ising nets[8], the proof of the existence of a Bose-Einstein condensation in interacting systems[9] (with Penrose), and a novel method of looking at the de Haas van Alphen effect[10]. He returned several times to the theory of electrolytes where his researches started (particularly in collaboration with Fuoss).

After retiring from Yale in 1972 Onsager went to the University of Miami. He remained healthy and vigorous until his death; the photograph was taken only a few months before he died.

Onsager held honorary doctorates of several universities, including Cambridge and Oxford. Among his many awards were the Rumford Medal of the American Academy of Arts and Sciences, the Lorentz Medal of the Royal Netherlands Academy of Sciences, and the National Science Medal. He was elected a Foreign Member of the Royal Society in 1975. His colourful personality will be missed particularly at international gatherings.

C. Domb

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Dr William Nordberg, internationally known space scientist and Director of Applications at NASA's Goddard Space Flight Centre, near Washington, D.C., died on October 3, after a two year illness, from cancer. Born in 1930, Dr Nordberg was educated at the University of Graz in Austria, his native country. He emigrated to the U.S.A. in 1953 and after working for the U.S. Army Signal Corps as an atmospheric physicist, particularly on the International Geophysical Year rocket programme, he joined the newly formed NASA at the Goddard Space Flight Centre in 1959. His first post there was head of the physical measurement section, Meteorology Branch in the Satellite Applications Division. From there he progressively rose to higher management positions until his appointment as Director of Applications in 1974.

From the beginning of the U.S. satellite programme Dr Nordberg applied his enormous enthusiasm and powers of leadership to pioneering the development of remote sensors for observing the atmosphere from space vehicles. He was involved in the instrumentation of the early Tiros weather satellites and many of the infra-red radiometric instruments on the first Nimbus meteorological research satellite were developed and built under his direction. He was quick to realise the potential of remote sounding measurements, not only for research on the atmosphere, but also for the investigation of the properties of the earth's surface, and under his leadership microwave instrumentation for mapping the distribution of sea ice and other important surface features was flown. The success of the Landsat satellites, which have carried remote sensors for mapping a wide range of earth resources, owed not a little to Dr Nordberg's foresight and ability to organise and to interest people from a wide range of scientific disciplines. He successfully co-ordinated the activities of 300 principal investigators from 38 countries in the use of Landsat data.

Dr Nordberg received a number of awards including NASA's highest award, the Distinguished Service Medal. In September of this year, shortly before his death, he was elected to be a Fellow of the American Meteorological Society, a fitting tribute to his pioneering work in space meteorology.

Bill Nordberg, through his extensive travels, made friends in almost every country of the world. He will always be remembered for his enormous energy, his infectious enthusiasm for science and his tremendous zest for life which continued even right through his long and trying illness. By his tragically early death the international space research community has lost an outstanding scientist and many of us have lost a true and valued friend.

He leaves his wife, and his parents and brother in Austria.

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